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PHYTOTOXICOLOGY SURVEY

INVESTIGATION:

SOIL AND VEGETATION SURVEY IN THE VICINITY OF FELKER FALLS AND THE TARO LANDFILL STONEY CREEK (1995)

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STONEY CREEK (1995)

Report prepared by:

J. Craig Kinch
Standards Development Branch
Phytotoxicology Section
Ontario Ministry of Environment and Energy

Report No: SDB-042-3511-96

BACKGROUND and INTRODUCTION

The Hamilton District Office of the Ministry of Environment and Energy (MOEE) requested the assistance of the Phytotoxicology Section in the investigation of possible soil and vegetation contamination and vegetation damage associated with water seeps (or springs) emanating from the Niagara Escarpment in the Felker Falls Conservation Area, Stoney Creek. Local residents had noted tree decline in the areas of some of the seeps and expressed concerns that the damage may have been influenced by activities at the nearby Taro landfill. Specifically, the two primary concerns were that (1) leachate from the operating landfill may be impacting on the seeps and having an adverse effect on soil and vegetation chemistry and vegetation health and, that (2) changes in 1992 to the pattern of clean surface water discharge from the landfill and quarry area may have resulted in increased seep salinity.

This report summarizes the results of soil sampling conducted on September 26 and 27, 1995 by Craig Kinch and Dave McLaughlin, Phytotoxicology Scientists, Phytotoxicology Section, Standards Development Branch.

METHODOLOGY

Seven sampling sites were established along the face of the escarpment east of the Redhill Creek Tributary. Four of the sites (A1, TB, A2 and A3) were established at the location of active seeps (see attached figure). For comparison, two control sites (C1 and C3) were located along the same face of the escarpment but not in the area of active seeps. A third control site (C2), located on the escarpment west of the Redhill Creek Tributary, was an active seep hydrologically separated from the other seeps by the Redhill Creek Tributary. For the seep sites, soil and vegetation samples were collected from the immediate seep area and/or in areas of the seep with symptomatic vegetation. Similar collections were made in representative areas of the forest community at the non-seep control sites.

Soil:

Composite near-surface soil samples (0-5 cm) were collected in triplicate from each of the 7 sampling stations for inorganic chemical analysis. Similarly, samples were collected in duplicate for various types of organic analyses. Composite samples consisted of at least 50 individual core sections collected from random locations within a 10 m by 10 m plot and extracted using a 2 cm - diameter stainless steel soil corer. Soil samples collected for inorganic analysis were stored in plastic bags and those collected for organic analysis were stored in amber glass bottles.

Soil samples collected for inorganic analysis were air-dried, pulverized to pass through a 45 mesh sieve and stored in glass bottles. The prepared samples were then forwarded to the Ministry's laboratory on Resources Road, Etobicoke for analysis. All replicate soil samples were analyzed for the following inorganic parameters:

Chloride (Cl)
Beryllium (Be)
Magnesium (Mg)
Aluminum (Al)
Calcium (Ca)
Vanadium (V)
Chromium (Cr)
Manganese (Mn)
Iron (Fe)
Cobalt (Co)
Electrical Conductivity (EC)
Nickel (Ni)
Copper (Cu)
Zinc (Zn)
Molybdenum (Mo)
Cadmium (Cd)
Barium (Ba)
Lead (Pb)
Strontium (Sr)
Boron (B)
Sodium (Na)

Soil samples collected for organic analysis were stored frozen (-80°C) and were not further processed prior to analysis.

Each replicate sample from each site and depth was analyzed for PCBs (polychlorinated biphenyls), CBs (chlorobenzenes), PAHs (polycyclic aromatic hydrocarbons), and CPs (chlorophenols). The PCB/CB compounds and detection limits (in parentheses and expressed as ng/g - parts per billion) were as follows:

PCB - Total	(20)	1,3,5-trichlorobenzene	(2)
Octachlorostyrene	(1)	Hexachloroethane	(1)
Hexachlorobenzene	(1)	Pentachlorobenzene	(1)
1,2,3-trichlorobenzene	(2)	2,3,6-trichlorotoluene	(1)
1,2,3,4-tetrachlorobenzene	(1)	2,4,5-trichlorotoluene	(1)
1,2,3,5-tetrachlorobenzene	(1)	2,6- dichlorobenzyl chloride	(1)
1,2,4-trichlorobenzene	(2)	Hexachlorobutadiene	(1)
1,2,4,5-tetrachlorobenzene	(1)		

The PAH compounds and detection limits (in parentheses and expressed as ng/g) were as follows:

Naphthalene	(20)	Benzo(a)anthracene	(20)
Acenaphthylene	(20)	Chrysene	(20)
Acenaphthene	(20)	Benzo(b)fluoranthene	(20)
Fluorene	(20)	Benzo(k)fluoranthene	(20)
Phenanthrene	(20)	Benzo(a)pyrene	(40)
Anthracene	(20)	Benzo(g,h,i)perylene	(40)
Fluoranthene	(20)	Dibenzo(a,h)anthracene	(40)
Pyrene	(20)	Indeno(1,2,3-cd)pyrene	(40)

The chlorophenol compounds and detection limits (in parentheses and expressed as ng/g) were as follows:

2,3,4-trichlorophenol	(10)	2,4,5-trichlorophenol	(20)
2,3,4,5-tetrachlorophenol	(10)	2,4,6-trichlorophenol	(10)
2,3,5,6-tetrachlorophenol	(5)	Pentachlorophenol	(5)

Replicate samples from each site and depth were additionally analyzed for volatile organics and petroleum distillates. These compounds and detection limits (in parentheses and expressed as ug/kg) were as follows:

Dichloromethane	(20)	Ethylbenzene	(10)
trans-1,2-dichloroethene	(20)	1,1-dichlorethane	(20)
Chloroform	(10)	Bromoform	(10)
1,1,1-trichloroethane	(10)	Carbon tetrachloride	(10)
1,1,2-trichloroethane	(10)	Benzene	(10)
m- and p-xylenes	(10)	Toluene	(10)
o-xylene	(10)	Dibromochloromethane	(10)
Trichloroethene	(10)	1,2-dichlorobenzene	(10)
1,3-dichlorobenzene	(10)	1,4-dichlorobenzene	(10)
Tetrachloroethene	(10)	Chlorobenzene	(10)
Bromodichloromethane	(10)		

Solvent extracted residues from one of the 2 replicate samples from each site were further analyzed by gas chromatography-(fullscan) mass spectrometry [GC-(FS)MS] for further organic characterization.

Replicate soil samples from each of the sites were also analyzed for pesticide residues (phenoxys, triazines and ureas). The samples were analyzed by the Agriculture and Food Laboratory Services Branch of the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) in Guelph, Ontario. All replicate soil samples were analyzed for the following pesticides:

alachlor (ALA)
atrazine (ATR)
d-atrazine metabolite (DATR)
cyanazine (CNZ)
metolachlor (METOL)
triazine herbicides (TRI)
2,4 dichlorophenoxy butyric (2,4-DB)
dicamba (DIC)
mecoprop (MCPP)
2,4 dichlorophenoxy acetic acid (2,4-D)
pentachlorophenol (PCP)
4-(2-methyl-4-chlorophenoxy) butyric acid (MCPB)
other phenoxy herbicides (0.Ph.)
picloram (PIC)
urea herbicides (URE)
chloroxuron (CLX)

Vegetation:

Vegetation collections were also conducted at each of the sampling stations. Duplicate foliar and twig samples (current and previous years growth) from sugar or black maple trees (depending on availability) were collected using pole pruners from the mid-crown of a sample tree at each site. Samples for inorganic analysis were stored in plastic bags during transport to the Phytotoxicology processing lab. These samples were oven-dried, ground in a Wiley-mill and stored in glass bottles. Processed vegetation samples were submitted to the MOEE laboratory for inorganic elemental analysis. Samples for organic analysis were stored in glass jars during transport to the Phytotoxicology processing lab. The samples were transported under dry ice and stored at -80°C. The samples were then forwarded to the MOEE's and/or OMAFRA laboratories for chemical analysis.

Foliage and twig samples were submitted for the same inorganic parameters analyzed in soils excluding electrical conductivity and including S (sulphur) and K (potassium). Foliage samples were also submitted for volatile organics/petroleum distillates analysis.

RESULTS AND DISCUSSION

Site Descriptions:

The species composition at **Seep A1** was predominantly sugar and black maple with smaller representations of ash and hemlock. At Seep A1 there were 5 symptomatic trees on the mid slope and 1 symptomatic tree at the base of the seep. The symptomatic trees were both large and small. The foliar symptoms included marginal leaf necrosis and leaf chlorosis, tended to occur crown-wide and were confined to black and sugar maple trees. In addition there were 2 dead hemlock and 1 dead maple. The area with symptomatic trees was approximately 25 m wide and predominantly occupying the mid-part of the slope (30 m in length). Generally, the ground cover vegetation was healthy in the general area of the seep with the very wet areas of the seep being dominated by jewel weed.

Control C1 (NON-SEEP) is located just northeast of Seep A1 and halfway between Seep A1 and Seep TB. There was no active seep present at this site. Vegetation in the area was very healthy with no unusual signs of foliar stress. There were, as in any forested community, the occasional dead older trees. The predominant vegetation was sugar and black maple with minor representation of ash and hemlock.

The species composition at **Seep TB** was similar to that at Seep A1 except that there was a slightly higher ash component (5-10 %) in the vicinity of this seep. Although foliar symptoms were similar, there were more symptomatic trees (12 trees) at this site than at Seep A1. The area affected was slightly narrower (20 m) than at Seep A1 but extended over a longer pitch from the top of the slope to the bottom. The symptoms were confined to maple (ash not affected) and symptomatic trees varied in size. In addition to the 12 symptomatic trees, there were 2 uprooted hemlock in the immediate seep area and 3 trees that had recently died. As with Seep A1, the ground cover vegetation was healthy in the general area of the seep with the very wet areas being dominated by jewel weed.

Unlike the above mentioned seeps, **Seep A2 (T-DS)** was more of a surface water course and consisted of a deep cut in the escarpment face in an area of the escarpment that was more gradual. There was little if any vegetation in the cut until the bottom of the escarpment where the cut meets the Redhill Creek Tributary. There were 3 symptomatic maple on the edge of this low, wet area as well as 5 dead maple and 2 dead hemlock. There were 12 other dead trees between 1 and 4 inches in diameter in the centre of the wet area that almost certainly died of waterlogging.

Seep A3 was a much drier site than the other seeps at the time of the survey but appeared to affect a wider area of the escarpment than the other seeps (approximately 50 m wide and 60 m down the escarpment face). The trees on the top 10 m of the escarpment (above the seep) were healthy. There was fairly substantial mortality down the rest of the escarpment face (with 14 mature and 18 understorey standing dead). Based on the degree of bark retention, and the deterioration of the fine twig structure in the crown, the mature trees appeared to have died some time ago (3 or 4 years) while the understorey trees died more recently (within the last 1 or 2 growing seasons). There were at least 3 trees on the escarpment face that were knocked down by the shifting face of the escarpment (soil and rock erosion). There was only one tree along this section of the escarpment exhibiting foliar necrosis and chlorosis similar to that found at the other sites. It was not until the very lower section of the escarpment, where the soil was moist and jewel weed present, that there were any trees (3 mature sugar maple) with the characteristic necrosis and chlorosis.

Control Seep C2 is located directly across the creek from Seep A3 and is approximately 30 m wide and covering approximately 40 m of slope. This seep is separated from the Taro side of the escarpment by the Redhill Creek Tributary and the creek's gorge. As with the other sites the predominant vegetation was sugar and black maple with minor representation of ash, hemlock and walnut. The ground cover was almost exclusively jewel weed. There were no signs of symptomatic trees in the seep.

Control C3 (NON-SEEP) is located just northeast of Seep A3. There was no active seep present at this site. Vegetation in the area was very healthy with no unusual signs of foliar stress or mortality. The predominant vegetation was sugar and black maple with minor representation of ash and hemlock.

Insect activity and disease infection are endemic in any forest community. Normal levels of common insects and disease were present in the study area. However, insects and disease were not involved as primary causal agents of any of the severe vegetation damage noted at any of the sampling locations. Specifically, Pear Thrips were not present at injurious levels on sugar maple. This insect has recently caused significant damage to escarpment hardwood forests between St.Catharines and Niagara Falls.

Inorganic Chemistry:

The analytical results for inorganic elements in **soil** are presented in Table 1. The data are µg/g (micrograms per gram, commonly referred to as parts per million) mean of triplicate samples and analysis except for electrical conductivity (EC) which is mS/cm.

There was a clear indication that the soils collected from beneath trees in the seeps had been impacted by the salinity of the seeps. The concentrations of Cl, Na and EC were particularly high, in exceedence of established guidelines, and in the range expected to cause damage to vegetation at Seeps A1 and TB (Appendix III explains the relative toxicity of soil EC). Concentrations of Ca were similarly elevated at these seeps (particularly Seep A1) but were probably not responsible for the damage, as evidenced by elevated Ca concentrations and correspondingly healthy vegetation at control sites C1 and C2. Soil salinity, as estimated by EC, was also in exceedence of the OTR guideline at each of the other seeps, including the control seep (C2). The concentrations of Sr were also elevated at Seep TB and particularly at Seep A1. Strontium is found as a mineral in rock with the principal Sr minerals being celestite ($SrSO_4$) and strontianite ($SrCO_3$). Elevated Sr concentrations at these two seeps are probably the result of the solubilization of native minerals along the path of the seeps.

Generally, the soil inorganic data indicates that, with the exception of a few elements reflecting seep salinity, the concentrations of inorganics in soil collected from beneath symptomatic trees in the potentially impacted seeps were well within the range considered normal for a rural area and were comparable to soils collected from the control locations. Exceedences of the Upper Limit of Normal (ULN)[1] (see Appendix I) or Ontario Typical Range (OTR_{98})[2] (see Appendix II) guidelines for Mg, Mn and B at various locations were of no environmental significance and are likely associated with natural deposits in the area. For example, recent Phytotoxicology soil sampling has documented surface soil Mn concentrations up to 2,200 µg/g in remote rural parks. The concentration of Pb was unexpectedly high at Control C3 and to a lesser extent at Seep TB, however, there was no consistent trend for soils impacted by seeps on the Taro side of the gorge to have elevated soil Pb concentrations. Concentrations of Zn exceeding the ULN guideline were found at 3 of the 4 seeps found to have vegetation damage. While the elevations of Zn and Pb are noteworthy, the concentrations are not in a range that would be phytotoxic.

The analytical results for inorganic elements in **maple foliage** and **maple twigs** are presented in Tables 2 and 3, respectively. The data are µg/g except for Cl, S and K expressed as % dry weight. The results of the vegetation data loosely paralleled those for soils with elements indicative of seep salinity tending to be reflected in elevated foliar and twig chemistry. For example, Cl concentrations were consistently higher in both foliage and twigs for samples collected from seeps on the east side of the Redhill Creek gorge as compared to the control seep (C2) or Non-seep Control (C1 and C3) escarpment sites. Interestingly, all foliage samples collected, including the controls, had Cl concentrations exceeding the ULN confirming the existence of salt deposits and/or salty groundwater in the area. Foliar Cl concentrations at all three symptomatic seep sites were 5 to 10 times higher than the control sites even though the soil Cl levels and EC were elevated only at seeps A1 and TB (the EC at A2 and A3 were comparable to the control seeps). Foliar chemistry reflects the trees cumulative environmental exposure where as soil Cl levels can fluctuate through the growing season (Cl is very mobile in soil). Therefore, in order for Cl to accumulate to potentially phytotoxic concentrations in foliage at seeps A2 and A3 the soil salinity must have been higher earlier in the growing season. Calcium concentrations also tended to be higher in foliage (but not twigs) in samples collected from Seeps A1, TB and A2. As with soil, Sr concentrations were found to be higher in vegetation and twigs collected from Seeps A1 and TB. Unlike the above elements there was no consistent relationship between Na concentrations in soil and those in foliage or twigs. The only other exceedences of the ULN were for B in foliage collected from Seeps A1 and TB (90 and 99 µg/g, respectively). The urban ULN for B is 175 µg/g and concentrations above this level may be phytotoxic to some species of maple.

Therefore, the results of soil, foliar and twig inorganic chemistry suggest that the most likely causes of the observed foliar damage is seep salinity. In particular, at Seep A1 the Ca and Cl levels indicate a severe mineral imbalance, substantiated by high soil EC.

Organic Chemistry:

The concentrations of PCBs (polychlorinated biphenyls), CBs (chlorobenzenes) and CP (chlorophenols) in **soils** collected in this study were below the analytical detection limits for all samples except for the Non-Seep Control (C3) where there were trace concentrations of hexachlorobenzene (replicate concentrations of 3 and 2 ng/g). Similarly, the concentrations of 20 volatile organics and petroleum distillates were also in every case below the analytical detection limits for all soil samples.

The results of infrared spectroscopy and gas chromatography indicated that because there were no hydrocarbon profiles detected in the volatile petroleum distillates analysis, it is likely that the hydrocarbons detected in the analysis were from natural sources (pers. comm., Dr. Vince Taguchi, MOEE). The presence of camphene, limonene and borneol confirm the natural sources. These compounds are commonly associated with cellulose, a major component of plant cell walls (camphene and limonene) or natural plant terpenes (borneol).

The results of quantitative soil PAH analyses are summarized in Table 4. The data are in ng/g. The Guideline For Use at Contaminated Sites in Ontario includes effects based criteria for PAH's in surface soils in potable residential/parkland land use areas[3]. These guidelines are summarized in Table 4. The current MOEE OTR_{98} guidelines for PAHs in soils in urban parklands are ***provisional*** and currently under review (particularly benzo(k)fluoranthene), and therefore are used in Table 4 for information purposes only.

Trace PAH concentrations in soils were detected at all sites in surface soils. Those PAHs that were consistently found in at least trace concentrations were; naphthalene, phenanthrene, floranthene, pyrene, chrysene and benzo(b)fluoranthene. Benzo(a)anthracene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, dibenzo(a,h)anthracene and indeno(1,2,3,-cd)pyrene and were found at fewer sites. The soil PAH data do not, however, implicate the Taro landfill as a source of PAH because there was no trend at all towards high concentrations at the seep sites. In addition, in all cases the mean PAH concentrations were well below background and effects-based concentrations. The exception are the exceedences of the OTR_{98} guideline for naphthalene and benzo(k)fluoranthene. However, the OTR_{98} guideline for these PAHs are provisional, unrealistically low, and currently under review. In any case, even control sites exceeded the respective guidelines for these 2 PAHs. The results of infrared spectroscopy and gas chromatography also indicated the trace presence of some polynuclear aromatic hydrocarbons (PAH - phenanthrene and pyrene) and were attributed to diesel exhaust.

The concentrations of pesticides in soils collected in this study were below the analytical detection limits for all samples.

Like soil, the concentrations of 20 volatile organics and petroleum distillates in **foliage** were also in every case below the analytical detection limits for all foliage samples. Six of the 13 pesticides analyzed were also below the analytical detection limits for all of the samples collected. Detectable, albeit low, concentrations of herbicides were found in foliage at the following seeps:

Seep	Pesticide	Concentration (µg/g)	
		Rep.1	Rep. 2
TB	PCP	0.07	non-detect
	MCPB	non-detect	0.02
C1	CLX	0.37	0.37
C2	2,4-D	0.04	non-detect
	PCP	0.34	non-detect
	MCPB	0.05	0.05
	CLX	non-detect	0.23
C3	2,4-DB	non-detect	0.03
	DIC	0.01	0.01
	PCP	non-detect	0.03
	PIC	non-detect	0.03

The above data does not suggest that pesticides are involved in the observed vegetation symptoms at the seeps on the Taro side of the landfill, but rather reflects on the ubiquitous nature of some of these compounds.

Therefore, soil and vegetation data show no evidence of any contamination by the 72 organic compounds examined.

SUMMARY and CONCLUSIONS

This report summarizes the results of soil and vegetation sampling conducted near seeps along the Redhill Creek Tributary gorge and in the general vicinity of the Taro landfill. Area residents were concerned that (1) leachate from the Taro landfill may be impacting soils and vegetation via the seeps on the escarpment face and that (2) changes in 1992 to the pattern of clean surface water discharge from the landfill and quarry area may have resulted in increased seep salinity. Sampling sites were established along the face of the escarpment in the vicinity of Felker Falls of the Redhill Creek Tributary to address active seeps on the Taro side of the landfill. In addition, control sites were established along the same face of the escarpment but not in the area of active seeps and a control seep site located on the escarpment separated from the other seeps by the Redhill Creek gorge. Vegetation observations were made at each of the sites and soil and vegetation (tree foliage and twigs) samples were collected from each area.

Foliar symptoms of tree stress were found at each of the groundwater seeps investigated on the east side of the Redhill Creek gorge. These symptoms, which were characteristic of salt injury, were found only at the seep sites. The symptoms of foliar stress were present only on black and sugar maple trees. The number of trees affected at each site was low, ranging from a high of 12 symptomatic trees to 3 trees at the least affected site. Foliar symptoms were most severe at Seeps A1 and TB and the least severe at Seeps A2 and A3. Tree mortality was also higher at the seep sites than at the control sites. However, with the exception of Seep A3 and considering the severity to the terrain, the level of mortality at the Seeps A1, TB and A2 may not be unusual. The level of mortality at Seep A3 could not be explained by any physical phenomena observed at the site. The time of tree mortality varied from within the last one or two growing seasons for some saplings at a few seeps to 3 to 5 years for the mature trees.

There was a clear indication that the soils collected from beneath trees in the seeps with the most obvious foliar symptomology (Seeps A1 and TB) had been impacted by the salinity of the seeps. The concentrations of Cl, Na and EC were particularly high, in exceedence of established guidelines, and in the range expected to cause damage to vegetation. This trend was, to a lesser extent, also evident in the foliar and twig chemistry data and provided further support for the contention that seep salinity was the primary causal factor of the observed foliar symptoms.

The results of analysis of extensive organic characterization of soils (PCB,CB,PAH,CP, volatiles, identification and pesticides) and vegetation (volatiles and pesticides) did not suggest that the seeps have contaminated the soils and vegetation nor does the data suggest that the foliar damage noted in the vicinity of the seeps was related to organic contamination.

REFERENCES

1. Ontario Ministry of the Environment. 1989. Ontario Ministry of the Environment "Upper Limit of Normal" Contaminant Guidelines for Phytotoxicology Samples - March 1989. ARB-138-88-PHYTO. Phytotoxicology Section -Air Resources Branch. Ontario Ministry of the Environment.

2. Ontario Ministry of Environment and Energy. 1993. Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow - December 1993. Hazardous Contaminants Branch. Ontario Ministry of Environment and Energy. HCB-151-3512-93.5.

3. Ontario Ministry of Environment and Energy. 1996 Guidelines for Use at Contaminated Sites in Ontario. Ontario Ministry of Environment and Energy. June 1996. ISBN 0-7778-4052-9. PIBS 3161E01.

Sketch map of soil and vegetation sampling locations in the vicinity of Felkers Falls, Stoney Creek (1995).

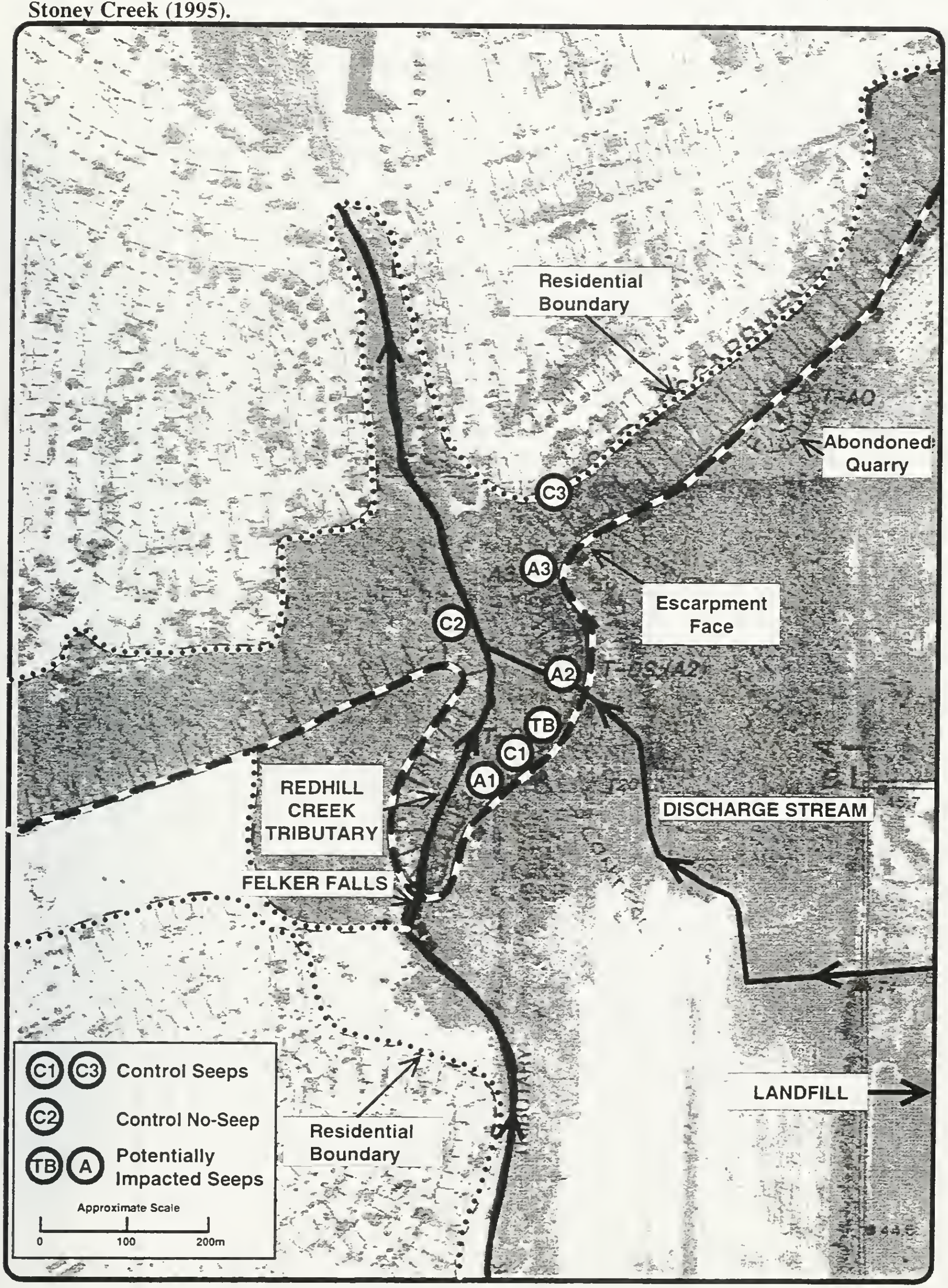

Table 1: Mean concentrations (µg/g) of inorganic elements in near surface (0-5 cm) soils collected in the Vicinity of Felker Falls and the Taro Landfill, Stoney Creek (1995).

SITE	Be	Mg	Al	Ca	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Mo	Cd	Ba	Pb	Sr	B	Na	Cl	EC (mS/cm)
SEEP AI	1 W	**31000**	3800	**230000**	7	6	540	6500	1.8	14	10	**670**	1	0.8	64	71	**780**	**22**	**1200**	**1600**	**2.2**
SEEP TB																					
AFFECTED TREE	0.9 T	**30000**	14000	54000	28	23	**1700**	23000	9.2	24	25	**670**	0.7 T	2.5	78	**180**	**120**	**33**	290	**82**	**0.6**
DIRECTLY IN SEEP	0.9 T	**45000**	18000	**79000**	33	25	**1900**	28000	16	29	34	**550**	2.3 T	1.8	93	84	**120**	**18**	**925**	**1400**	**2.1**
SEEP A2	0.8 T	**15000**	13000	24000	22	23	**880**	22000	12	22	24	390	0.9 T	1.4	72	51	38	**23**	97	26	**0.5**
SEEP A3	0.5 W	**23000**	9800	49000	20	20	**770**	16000	7.4	18	27	**900**	0.5 W	2.9	60	102	49	**30**	107	12	**0.5**
CONTROL NON-SEEP C1	0.5 W	**56000**	8500	**99000**	17	14	**1200**	15000	5.6	11	12	470	0.5 W	1.6	57	120	56	**15**	150	4	0.3
CONTROL SEEP C2	0.5 W	**25000**	2500	**64000**	8	9	**1500**	7000	2 T	8	32	400	0.7 W	1.9	58	96	44	**35**	73	13	**0.9**
CONTROL NON-SEEP C3	0.8 T	8800	13000	13000	31	22	**1500**	27000	11	18	22	410	0.5 W	2.1	60	**240**	14	**20**	77	3.8	0.3
ULN	1.1*	10000	30000*	55000*	70	50	700	35000	25	60	60	500	2	3	160*	150	64*	10**	660*	45**	0.36*

ULN	MOEE Upper Limit of Normal guidelines for soil in rural areas (see Appendix I).
EC	Electrical conductivity (see Appendix III)
*	No ULN guideline, OTR_{98} for rural parkland substituted (see Appendix II)
**	Provisional guideline
T	A measurable trace amount. Interpret with caution.
W	Below analytical detection limit, no measurable response (zero).

Values in bold and underlined exceed the guideline.

Table 2: Mean concentrations (µg/g - except Cl, S and K expressed as %) of inorganic elements in foliage collected from trees in the Vicinity of Felker Falls and the Taro Landfill, Stoney Creek (1995).

SITE	Al	Be	Ba	B	Ca	Cd	Co	Cu	Cr	Fe	Mg	Mn	Mo	Ni	Pb	Sr	V	Zn	Na	Cl	S	K
SEEP AI	92	0.2 W	12	**90**	25000	0.2 T	0.2 W	6.2	1.0	195	4000	56	0.3 T	0.5 W	1.6 T	340	0.5 W	21	33	**1.9**	0.21	0.76
SEEP TB	82	0.2 W	12	**99**	25000	0.1 W	0.2 W	5.5	0.5 W	230	3600	94	0.3 T	0.5 W	1.5 T	240	0.5 W	22	22	**1.2**	0.17	0.67
SEEP A2	46	0.2 W	23	56	28000	0.1 W	0.2 W	3.2	0.5 W	130	4200	130	0.2 W	0.5 W	1.4 T	84	0.5 W	18	19	**1.2**	0.18	0.50
SEEP A3	43	0.2 W	7.1	54	16000	0.2 T	0.2 W	8.2	0.5 W	88	2100	59	0.2 W	0.6 T	0.8 T	52	0.5 W	23	42	**0.84**	0.22	0.76
CONTROL NON-SEEP C1	120	0.2 W	5.7	46	16000	0.1 W	0.2 W	14	0.8 T	280	3400	63	0.2 W	0.7 T	3.3	67	0.5 W	36	30	**0.2**	0.29	1.3
CONTROL SEEP C2	98	0.2 W	8.0	67	20000	0.1 W	0.2 W	7.9	0.8 T	280	5200	36	0.2 W	0.5 W	1.6 T	21	0.5 W	30	29	**0.16**	0.20	0.63
CONTROL NON-SEEP C3	43	0.2 W	5.4	43	15000	0.1 W	0.2 W	7.9	0.5 W	120	3100	110	0.2 W	0.5 W	1.2 T	16	0.5 W	26	19	**0.21**	0.25	1.2
ULN	500	NG	NG	75	30000	1	2	20	8	500	7000	NG	1.5	5	30	NG	5	250	50	0.15	0.40	NG

ULN	MOEE Upper Limit of Normal guidelines for foliage in rural areas (see Appendix I).
T	A measurable trace amount. Interpret with caution.
W	Below analytical detection limit, no measurable response (zero).
Values in bold and underlined exceed the guideline.	
NG	No ULN Guideline

Table 3: Mean concentrations (µg/g - except Cl, S and K expressed as %) of inorganic elements in twigs collected from trees in the Vicinity of Felker Falls and the Taro Landfill, Stoney Creek (1995).

SITE	Al	Be	Ba	B	Ca	Cd	Co	Cu	Cr	Fe	Mg	Mn	Mo	Ni	Pb	Sr	V	Zn	Na	Cl	S	K
SEEP AI	26	0.2 W	4.8	21	12000	0.1 W	0.2 W	8.6	0.5 W	44	1040	34	0.4 T	0.5 W	0.5 W	200	0.5 W	22	64	0.11	0.06	0.72
SEEP TB	29	0.2 W	9.7	25	20000	0.2 T	0.2 W	14	0.5 W	100	950	66	0.5 T	0.6 T	0.8 T	260	0.5 W	38	160	0.07	0.08	0.72
SEEP A2	18 T	0.2 W	17	22	17000	0.2 T	0.2 W	9.2	0.5 W	58	1200	86	0.2 W	0.6 T	0.9 T	73	0.5 W	33	21	0.02	0.09	0.60
SEEP A3	18	0.2 W	9.5	24	15000	0.1 W	0.2 W	7.3	0.5 W	48	1100	82	0.4 T	0.5 W	0.5 T	95	0.5 W	46	12	0.055	0.08	0.68
CONTROL NON-SEEP C1	26	0.2 W	6.0	25	16000	0.1 W	0.2 W	15	0.5 W	70	1200	51	0.4 T	0.9 T	1.5 T	104	0.5 W	46	62	0.004 T	0.10	0.81
CONTROL SEEP C2	28	0.2 W	7.7	30	20000	0.2 T	0.2 W	6.0	0.5 W	67	2500	46	0.2 W	0.5 W	1.1 T	29	0.5 W	46	37	0.002 W	0.09	0.66
CONTROL NON-SEEP C3	39	0.2 W	7.4	59	16000	0.2 T	0.2 W	7.5	0.5 W	101	1900	79	0.2 W	0.5 W	0.5 W	44	0.5 W	22	46	0.007 T	0.09	0.86

T A measurable trace amount. Interpret with caution.
W Below analytical detection limit, no measurable response (zero).

Table 4: Mean concentrations (ng/g) of polycyclic aromatic hydrocarbons (PAHs) in surface soils (0-5 cm) collected in the Vicinity of Felker Falls and the Taro Landfill, Stoney Creek (1995).

SITE	SEEP A1	SEEP TB		SEEP A2	SEEP A3	CONTROL NON-SEEP C1	CONTROL SEEP C2	CONTROL NON-SEEP C3	OTR[1] Guidelines	Guideline for Use at Contaminated Sites in Ontario[2]
		Affected Tree	Directly in Seep							
COMPOUNDS										
Naphthalene	60 T	60 T	100	100	40 T	100	80 T	80 T	90p	4600
Acenaphthylene	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	96	100000
Acenaphthene	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	160	15000
Fluorene	(20)	(20)	(20)	(20)	(20)	(20)	(20)	(20)	140	340000
Phenanthrene	(20)	60 T	(20)	60 T	80 T	40 T	(20)	40 T	1400	40000
Anthracene	(20)	(20)	(20)	(20)	(20)	(20)	120	(20)	230	28000
Fluoranthene	40 T	80 T	(20)	60 T	120	40 T	(20)	60 T	1600	40000
Pyrene	(20)	60 T	(20)	40 T	80 T	40 T	140	40 T	1200	1300
Benzo(a)anthracene	(20)	(20)	(20)	(20)	40 T	(20)	120	(20)	690	6600
Chrysene	(20)	40 T	(20)	40 T	60 T	(20)	60 T	(20)	940	12000
Benzo(b)fluoranthene	40 T	60 T	(20)	60 T	100	40 T	80 T	60 T	1600	12000
Benzo(k)fluoranthene	(20)	(20)	(20)	(20)	40 T	(20)	120	(20)	(6)p	12000
Benzo(a)pyrene	(40)	(40)	(40)	(40)	80 T	40 T	40 T	(40)	810	1200
Benzo(g,h,i)perylene	(40)	(40)	(40)	(40)	(40)	(40)	80 T	(40)	610	40000
Dibenzo(a,h)anthracene	(40)	(40)	(40)	(40)	(40)	(40)	80 T	(40)	360	1200
Indeno(1,2,3-cd)pyrene	(40)	(40)	(40)	(40)	(40)	(40)	80 T	(40)	460	12000

1 MOEE Ontario Typical Range for PAHs in rural parkland soils (see Appendix II).
2 Guidelines for Use at Contaminated Sites - PAHs in residential/parkland soils in a potable situation (MOEE, 1996).
p Provisional OTR_{98}
T A measurable trace amount. Interpret with caution.
Note: Values in parentheses are below analytical detection limit (detection limit in parentheses), no measurable response (zero).

APPENDIX I

Derivation and Significance of the MOEE Phytotoxicology "Upper Limits of Normal" Contaminant Guidelines.

The MOEE Upper Limits of Normal (ULN) contaminant guidelines represent the expected maximum concentration in surface soil, foliage (trees and shrubs), grass, moss bags, and snow from areas in Ontario not exposed to the influence of a point source of pollution. Urban ULN guidelines are based on samples collected from developed urban centres, whereas rural ULN guidelines were developed from non-urbanized areas. Samples were collected by Phytotoxicology staff using standard sampling procedures (ref: Ontario Ministry of the Environment 1983, Phytotoxicology Field Investigation Manual). Chemical analyses were conducted by the MOEE Laboratory Services Branch.

The ULN is the arithmetic mean, plus three standard deviations of the mean, of the suitable background data. This represents 99% of the sample population. This means that for every 100 samples which have not been exposed to a point source of pollution, 99 will fall within the ULN.

The ULNs do not represent maximum desirable or allowable limits. Rather, they are an indication that concentrations that exceed the ULN may be the result of contamination from a pollution source. Concentrations that exceed the ULN are not necessarily toxic to plants, animals, or people. Concentrations that are below the ULN are not known to be toxic.

ULNs are not available for all elements. This is because some elements have a very large range in the natural environment and the ULN, calculated as the mean plus three standard deviations, would be unrealistically high. Also, for some elements, insufficient background data is available to confidently calculate ULNs. The MOEE Phytotoxicology ULNs are constantly being reviewed as the background environmental data base is expanded. This will result in more ULN being established and may amend existing ULNs.

APPENDIX II

Derivation and Significance of the Ontario Ministry of Environment and Energy (MOEE) "Ontario Typical Range" of Chemical Parameters in Soil, Vegetation, Moss bags and Snow

The MOEE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the* OTR_{98} *is the actual guideline numbe*r) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOEE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOEE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average,* and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific*** OTR_{98} ***should not be considered as acceptable or desirable levels; nor does the*** OTR_{98} ***imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types.

APPENDIX III

Soil Conductivity

Soil electrical conductivity (EC) is a measure of the total salts in the soil. Although EC is most commonly used to assess the degree of soil salt contamination from natural salt deposits, the use of winter de-icing compounds on roads, and the application of brine solutions for summer roadway dust control, EC also includes the measure of natural soil mineral and nutrient salts. An elevated soil EC can interfere with the plant's ability to absorb moisture and essential nutrients from the soil. An excessively elevated soil EC reverses the soil's natural osmotic pressure gradient and can actually draw moisture out of the plant. Therefore, plants exposed to salt-contaminated soil may be deprived of adequate moisture and nutrients, or in extreme cases, become desiccated as if experiencing severe drought, even though soil moisture is not limited.

The Phytotoxicology Processing Laboratory conducts soil EC measurements on a 2:1, water:soil suspension. The Ontario Ministry of Agriculture and Food (OMAF) publication 296 (*Ontario Field Crop Recommendations, 1987)* contains a table that relates soil EC to phytotoxic response. This table is reproduced below. The unit of measure is millisiemens/cm (mS/cm, note: 1 siemen = 1 mho). OMAF considers an EC of 0.7 mS/cm to be excessive. However, an EC as low as 0.5 mS/cm can injure salt-sensitive plants.

Soil EC Interpretation

EC ("Salt") millisiemens/cm	Rating	Plant Response
0-0.25	L	Suitable for most plants if recommended amounts of fertilizer are used.
0.026-0.45	M	Suitable for most plants if recommended amounts of fertilizer are used.
0.46-0.70	H	May reduce emergence and cause slight to severe damage to salt sensitive plants.
0.71-1.00	E	May prevent emergence and cause slight to severe damage to most plants.
1.00	E	Expected to cause severe damage to most plants.

L - Low
M - Moderate
H - High
E - Excessive